

# QUANTUM IMAGING TECHNIQUES

**Timea Szöllősová\***

**16/09/2025**

**8th Workshop on Diffraction and Ultra-peripheral Collisions in Děčín**

**\*University of Padova and Czech Technical University in Prague**

WHAT?

# WHAT?

- ★ my future FEE BSc. thesis
  - Department of Radioelectronics
  - Dr. Fliegel
- ★ so far only “rešerš”
  - afterall, in the meantime, I am in Italy

WHAT?

# WHAT?

- ★ no quantum sensing (MM :) )
- ★ quantum ghost imaging
  - a bit of classical too
- ★ quantum radar

SPOOK

# IMAGING

PHOTON  
SOURCE



CCD CAMERA

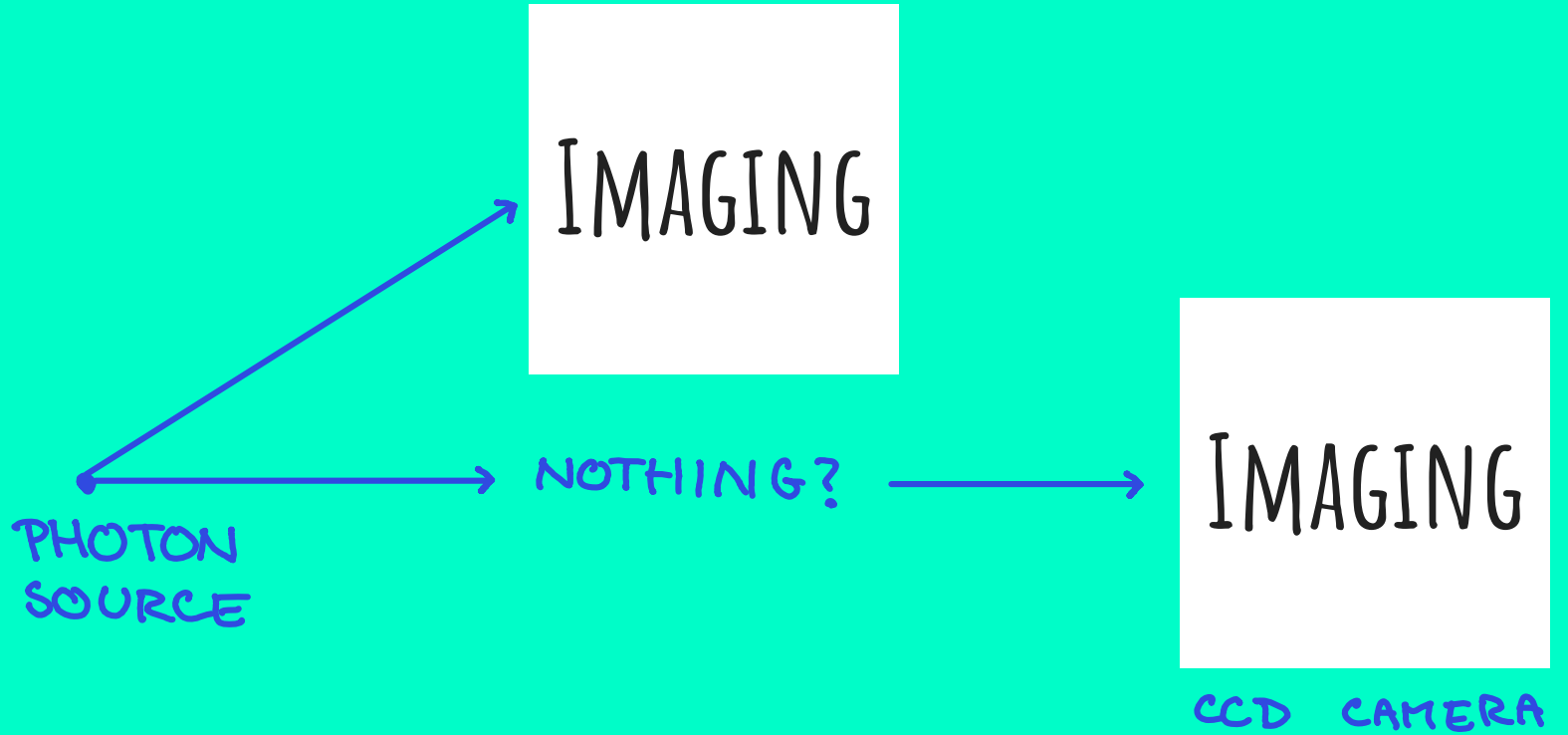
PHOTON  
SOURCE

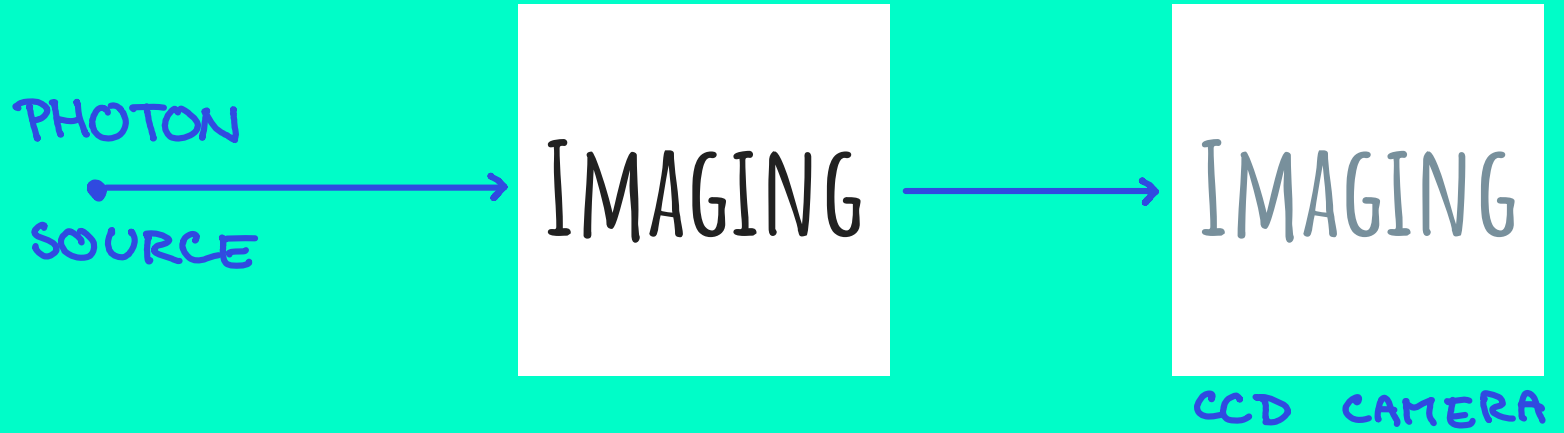


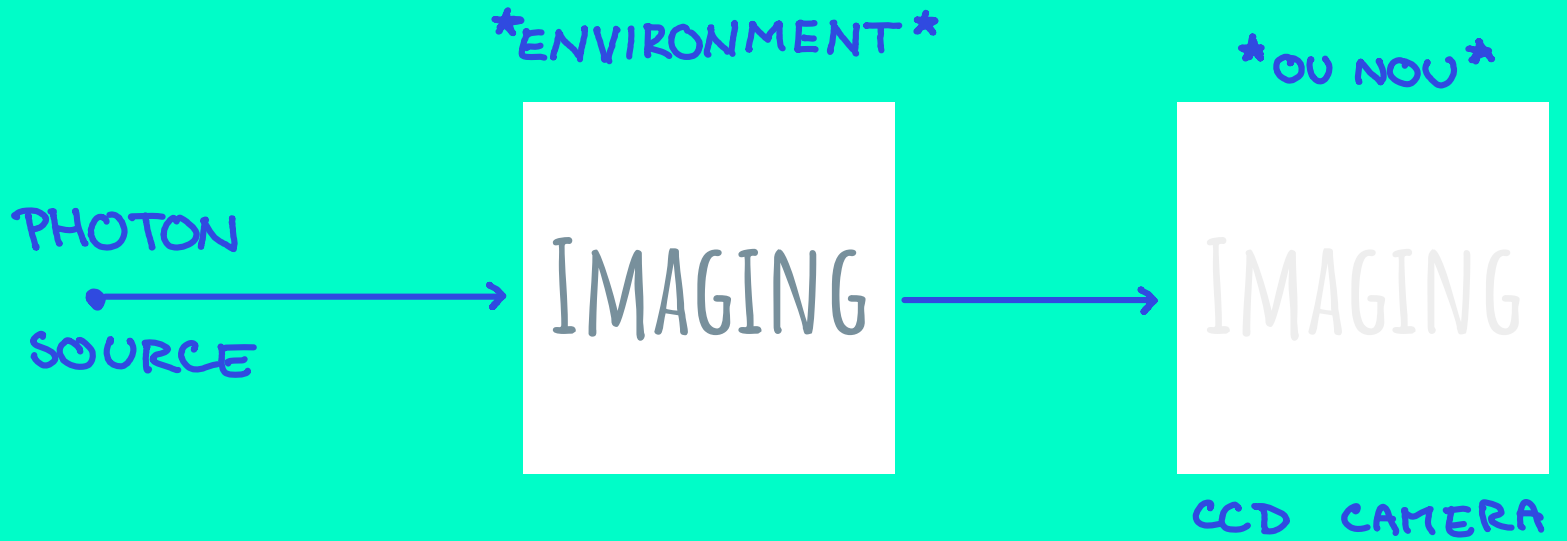
NOTHING?

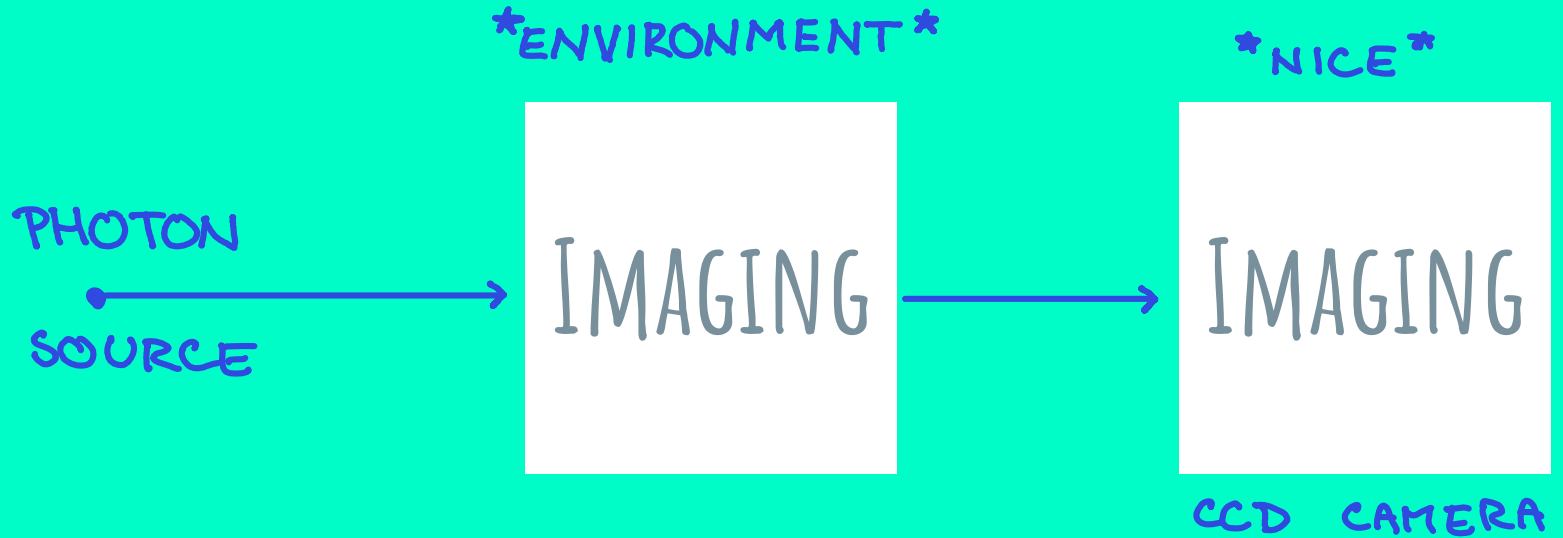


CCD CAMERA









QUANTUM

# SPONTANEOUS PARAMETRIC DOWN CONVERSION

- ★ photon pump
  - high frequency
- ★ nonlinear crystal
  - temperature dependence
- ★ phase matching conditions
  - conservation laws (E, p)

- biphoton state
  - ◆ signal & idler
- not too efficient

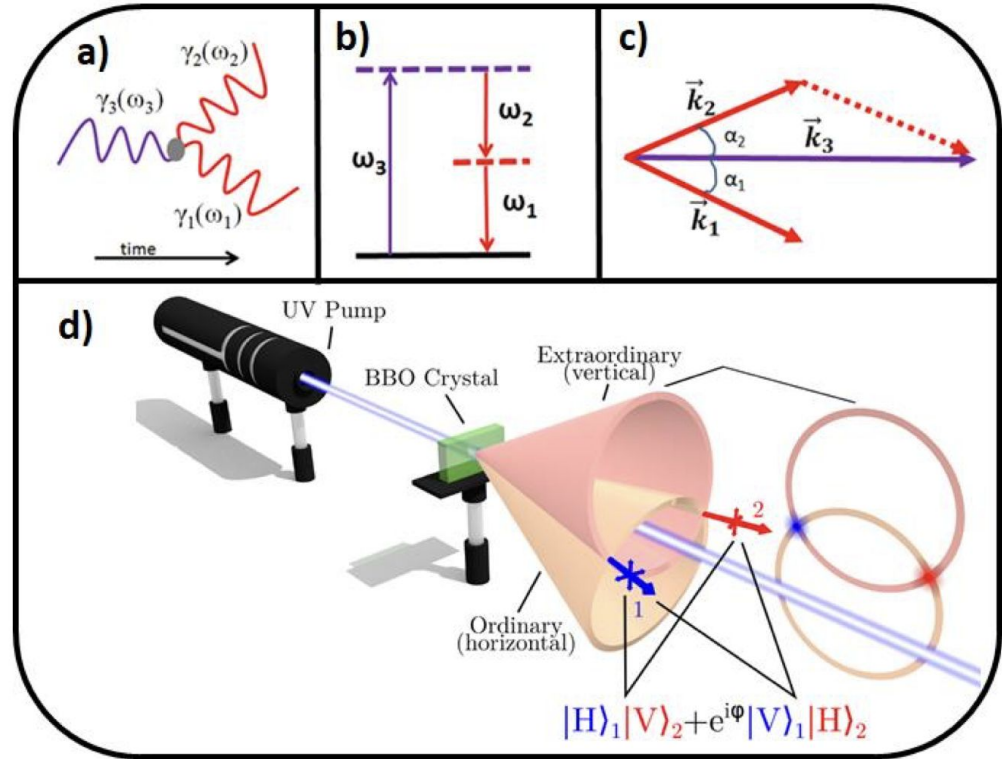


Figure 1: a) Feynman's diagram of SPDC where one photon at energy  $\hbar\omega_3$  splits into two twin photons at energies  $\hbar\omega_2$  and  $\hbar\omega_1$  and b) representation of energy conservation of SPDC, c) is the representation of momentum conservation of SPDC and d) is a schematic of SPDC where a UV pump laser generates red SPDC photons coming out of the crystal in a cone shape.

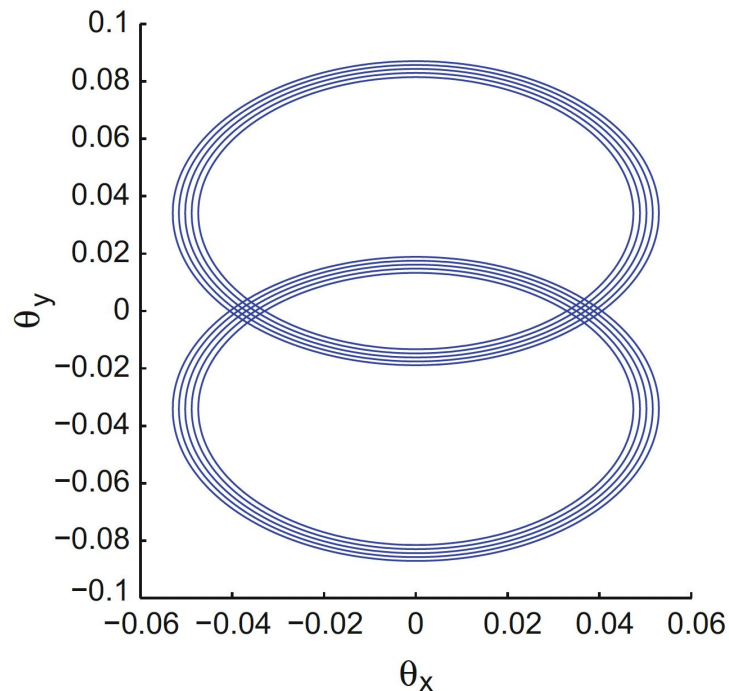
# SPONTANEOUS PARAMETRIC DOWN CONVERSION

I type

- ★ same polarisation  
→ e → o + o
- ★ higher conversion efficiency
- ★

II type

- ★ orthogonal polarisation  
→ e + o
- ★ enables polarisation entanglement

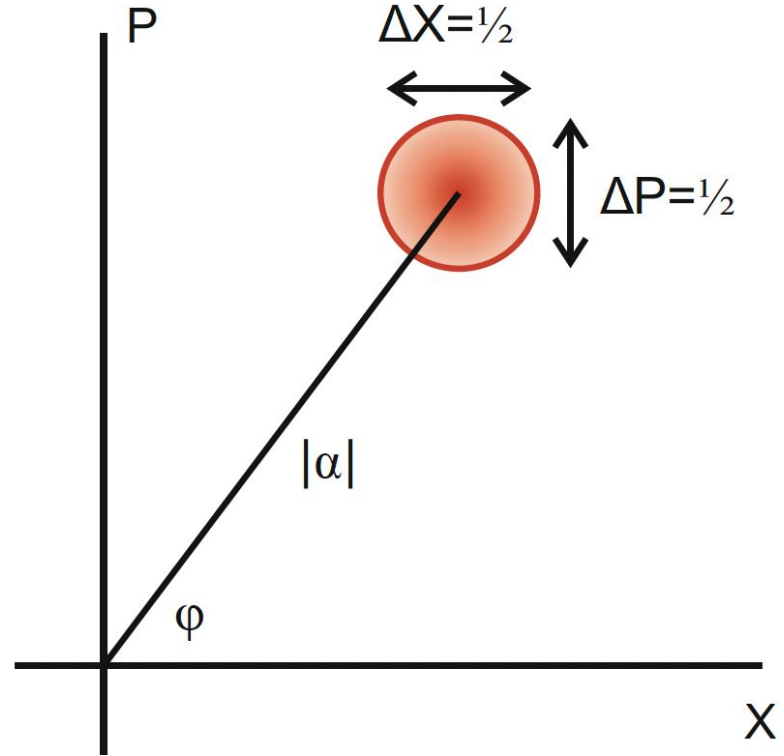
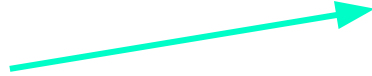


→ 
$$|\Psi\rangle = \frac{1}{\sqrt{2}} (|H\rangle_s |V\rangle_i + |V\rangle_s |H\rangle_i)$$

# SQUEEZED STATES

= reduced uncertainty in one quadrature below the shot noise

★ coherent states:

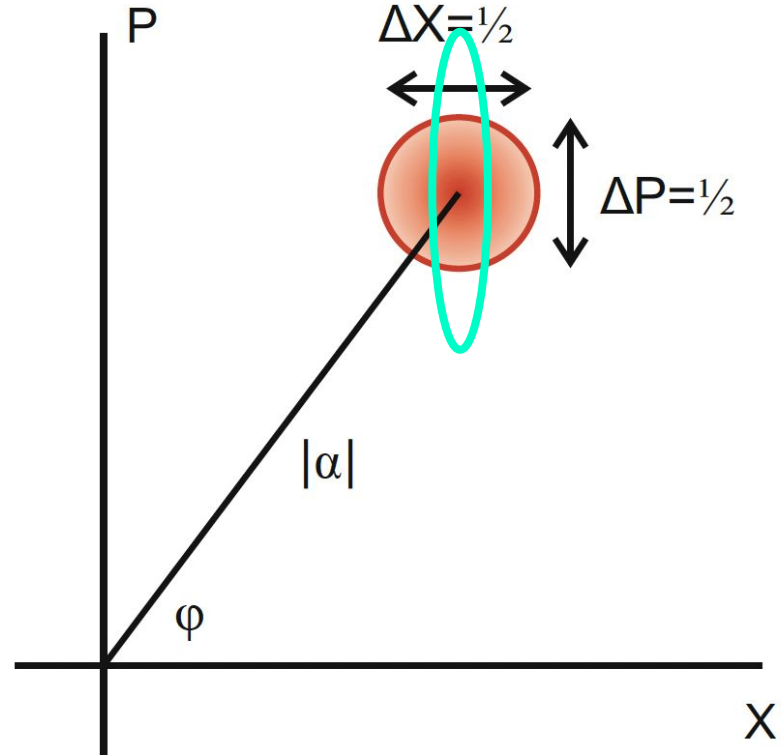
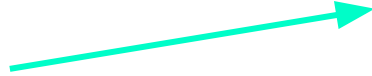


# SQUEEZED STATES

= reduced uncertainty in one quadrature below the shot noise

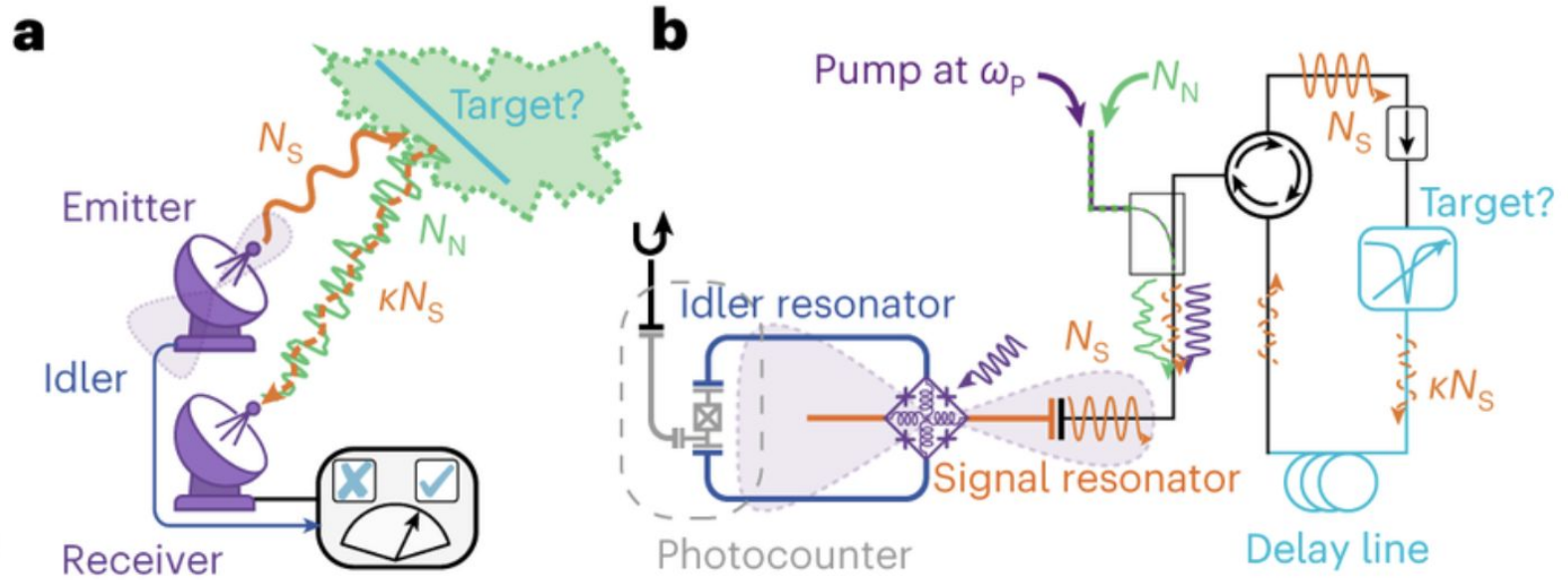
- ★ squeezed states:
- ★ two-mode squeezed vacuum

→ sub-shot noise

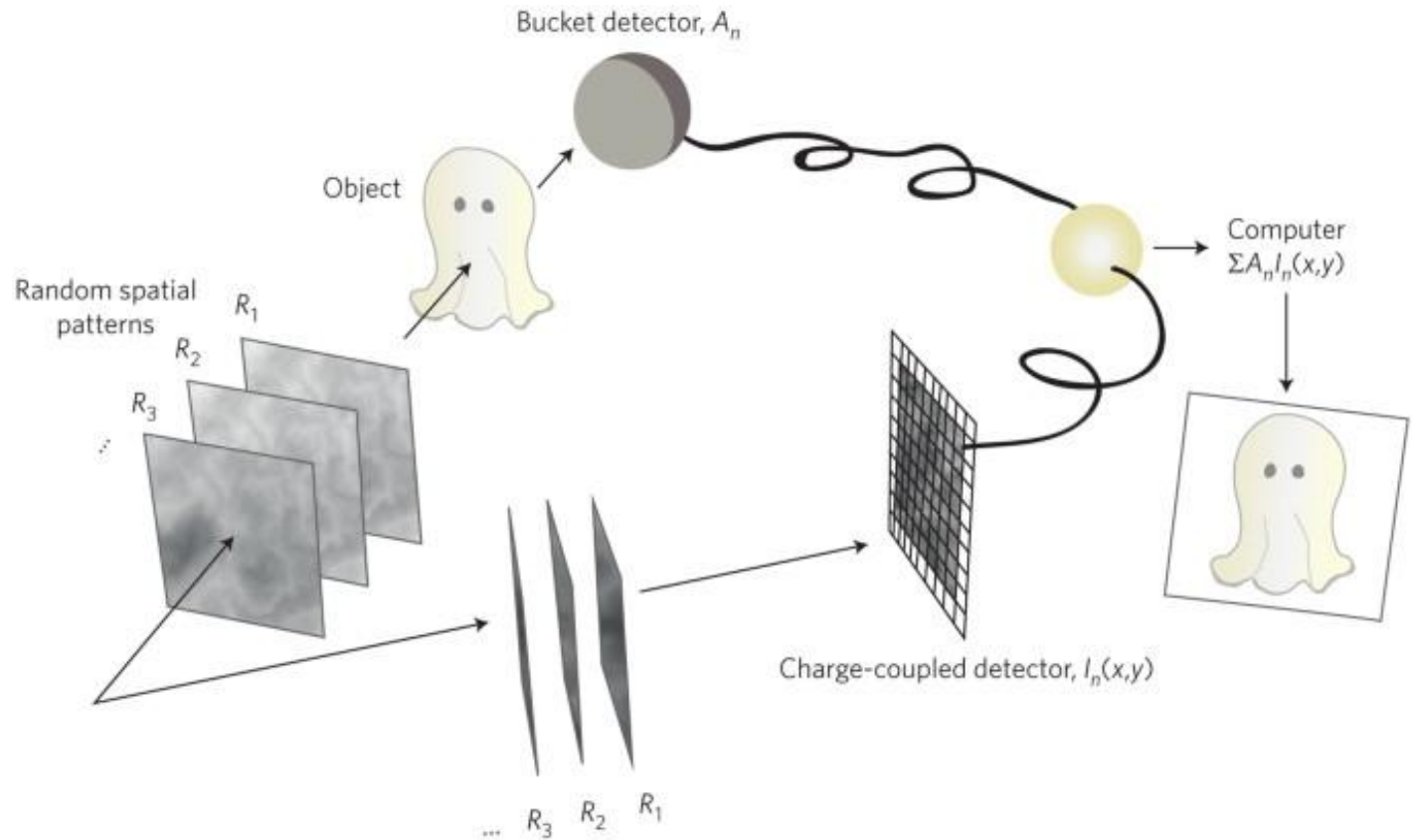


# TECHNIQUES

# QUANTUM RADAR



# GHOST IMAGING



# QUANTUM AND? CLASSICAL

pseudo-thermal source for  
classical correlations  
production

- ★ quantum
  - phase sensitive
- ★ classical
  - higher flux
- ★ computational
  - single detector
  - simulation of the other photon
- ★ compressive
  - reduces the measurement requirements

# FUTURE OUTLOOK

Me? just simulations :(

The world:

★ expanding wavelength  
range

★ algorithmic gains

★ hardware integration

→ Lidars

→ medical approval

→ defense...

# SOURCES

- ★ <https://doi.org/10.1038/nphoton.2016.30>
- ★ [10.1038/s41567-023-02113-4](https://doi.org/10.1038/s41567-023-02113-4)
- ★ <https://doi.org/10.48550/arXiv.1809.00127>

1. Ivan Djordjevic. Quantum Communication, quantum networks, and Quantum Sensing. Academic Press, 2022.
2. David S. Simon, Gregg Jaeger, and Alexander V. Sergienko. Quantum Metrology, Imaging, and Communication. Springer, July 2018.